Inference of molecular divertor density from filtered camera analysis of molecularly induced Balmer line emission during detachment in JET L-mode plasmas

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Deuterium Balmer D_α and D_γ emission contributions arising from molecular processes have been distinguished experimentally in the JET divertor during detachment in L-mode plasmas utilizing tomographic reconstructions of filtered camera images. The Monte Carlo method presented in [1,2] for estimating local plasma conditions in 2D based on intensity ratios of D_α, D_γ and D_ε lines was expanded to consider also the molecularly induced component, which has previously been observed to potentially dominate the D_α intensity at the onset of detachment [3,4]. This improves the accuracy of interpreting the Balmer line emission and allows inference of local estimates for the molecular divertor density.

The excitation arising from molecular processes was found to account for up to 60—80% of the D_α emission near the outer strike point, peaking at strike-point electron temperatures of $T_{e,osp} = 1.0$—1.5 eV and decreasing beyond the roll-over of the target ion current at $T_{e,osp} \approx 1.0$ eV to below 20% in deep detachment. For D_γ, maximum contributions of 10—20% are estimated at $T_{e,osp} > 2.0$ eV. The observations are in qualitative agreement with predictions of EDGE2D-EIRENE [5—7] simulations for which the molecularly induced Balmer emission was post-processed using the molecular databases of EIRENE. Quantitatively, the experimental estimates primarily lie within the range between EDGE2D-EIRENE predictions with the H_2 molecules in their vibrational ground state and with their vibrational population distributions calculated with the EIRENE molecular data by the Python tool CRUMPET [8].

Molecular densities, n_{mol}, can be inferred from the separated molecularly induced D_α and D_γ contributions using the EIRENE functionalities, suggesting an increase of n_{mol} near the outer strike point up to the order of 10^{21} m^{-3} in deep detachment at $T_{e,osp} < 1.0$ eV with similar values obtained from the independent analyses of D_α and D_γ. The resulting ratio between n_{mol} and electron density at the outer strike point is found to agree within the scatter of the experimental data with the EDGE2D-EIRENE predictions, when the vibrational H_2 population distributions calculated by CRUMPET are considered.

The calculations of the molecularly induced Balmer line emission and, consequently, the values of n_{mol} inferred from the emission contributions, were found to depend strongly on the assumptions of the vibrational states of the H_2 molecules, indicating need for deeper understanding of the vibrational excitation in the studied plasmas for improved accuracy of the experimental n_{mol} estimates. The results may also be affected by the considered isotope, as reaction rates for H_2 were used for analyzing deuterium plasmas in lack of corresponding rates for D_2. Moreover, the experimental estimates for the molecular emission contributions potentially include also the emission-amplifying effect of Lyman-series opacity [9], whose significance will be addressed in future studies.

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